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ABSTRACT

Performance on standardized figural analogy tests is considered highly predictive of academic success. While information-processing models of analogy solution attribute performance differences to quantitative differences in processing parameters, the problem-solving literature suggests that qualitative differences in problem representation and solution strategies may critically determine individual differences in performance. A study was conducted assessing eye movement patterns of high and low scorers on a figural analogy test during analogy solution to investigate strategic differences. Six of the highest and lowest scorers on one adult-level Cognitive Abilities Test (CAT) figural analogy subtest each solved 50 problems from two other CAT subtests shown on slides. A computer-based eye view monitor system was used to determine eye position. Data were summarized in terms of the number and duration of fixations made within the problem stem, answer alternatives, and between the problem stem and answer alternatives. The general pattern of results is consistent with the view that high scorers use a constructive strategy while lower scorers use an eliminative approach. High scorers appear to represent and solve problems in a qualitatively different way than do low scorers. This difference bears some resemblance to expert/novice differences in problem solving. (NB)

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QUALITATIVE DIFFERENCES IN REAL-TIME SOLUTION OF STANDARDIZED FIGURAL ANALOGIES

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Major Purpose:

Performance on standardized figural analogy tests is highly predictive of academic success and commonly viewed as a 'knowledge-free' measure of aptitude (Snow, 1980; Sternberg, 1977). Major information-processing models of analogy solution attribute performance differences to quantitative differences in processing parameters, not to qualitative differences in problem representation and solution strategies (Mulholland, Pellegrino & Glaser, 1980; Sternberg, 1977). Yet the problem-solving literature suggests that such qualitative differences may critically determine individual differences in performance (e.g., Chi, Feltovich & Glaser, 1981; Newell & Simon, 1972; see also Just & Carpenter, 1985).

Recent work has shown that high scorers on the figural analogies of the Cognitive Abilities Test (CAT) -- like experts in many domains -- tend to represent and remember problems in terms of a coherent system of abstract, well-constrained transformational relationships, while low scorers -- like novices -- tend to focus more on loose surface (i.e., figural) similarities among problem terms (Schiano, Cooper & Glaser, 1983; Schiano, 1985). Thus, aptitude-related qualitative differences in problem representations have been demonstrated. The purpose of the present experiment is to extend upon this initial work by investigating aptitude-related qualitative differences in real-time CAT problem solution.

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Snow (1980; see also Betthel-Fox, Lohman & Snow; 1983) differentiates two broad categories of strategies used on standardized spatial reasoning tests: constructive matching and response elimination. The "top-down" constructive matching approach involves the systematic study of problem terms, and the generation of an "idea" answer, which is then compared to answer alternatives for the best match. The more "bottom-up" response elimination approach involves the arrival at an answer through a process of eliminating incorrect alternatives via feature comparison. The former is taken to reflect a more skilled (or 'apt') approach than the latter. In this experiment, the eye movement patterns of high and low scorers were assessed during analogy solution in order to investigate whether such strategic differences might be observed.

Subjects:

Six of the highest and lowest scorers on one adult-level CAT figural analogy subtest (see Thorndike & Hagen, 1974) were chosen from a large population of University of Pittsburgh undergraduates. None wore corrective lenses.

Procedure:

Each subject solved 50 problems from two other CAT subtests, shown on slides with problem stem terms centered above the five answer alternatives. Trials were self-initiated. A Gulf & Western 1996S Computer Based Eye View Monitor (EVM) system determined eye position from calibrated infra-red pupillary and corneal reflections, recorded 60 times/second. Data was summarized in terms of the number and duration of fixations made within the problem stem (A:B::C:?), answer alternatives (D1-D5), and between the problem stem and answer alternatives.

Results:

Considering first the patterns of encoding the problem stem, the overall distribution of fixations was similar for both groups, except for direct comparisons between the A and C terms. Lower scorers spent significantly more time in mapping the A:B relation than did the higher scorers ($F(1,10)=4.93$;

$p<.05$); their average A:B trip time was longer ($F(1,10)=5.89$; $p<.05$), and they spent more time re-fixating the A term during these trips than did the high scorers ($F(1,10)=6.49$; $p<.05$). The ratio of total time spent comparing A:B as opposed to A:a for the high scorers was .24, while that for the low scorers was the critical A:a transformation than in mapping figure A onto figure B.

In addition, lower scorers devoted more fixations to answer alternatives than did higher scorers ($F(1,10)=5.53$; $p<.05$), spending more total time on the answers ($F(1,10)=4.43$; $p<.05$). A marginally significant difference suggests that lower scorers considered more answer alternatives overall than did the higher scorers ($F(1,10)=4.43$; $p<.10$); they also took significantly longer to consider the answers, alternative glances between problem stem terms and answer alternatives ($F(1,10)=7.87$; $p<.05$).

(Effects of problem difficulty were assessed by comparing results for the five easiest and hardest problems, as determined by accuracy norms. With increased difficulty, all subjects increased A:B mapping, as assessed by such measures as time and number of A:B trips. In addition, all subjects spent more time both in considering answers, and in comparing answer alternatives with stem terms. Thus, with increased difficulty, the pattern for the high scorers looked much more like the overall pattern for low scorers. With one interesting exception: For initial stem fixations prior to viewing any answer alternative, a trend toward an interaction with aptitude level was found ($F(1,10)=3.60$, $p<.10$), suggesting that high scorers chose to devote more fixations towards initially encoding the stem terms on more difficult problems than did the lower scorers).

Conclusions:

The observation that low scorers spent more time on the less critical A:B figural relation than on the primary A:a transformation -- while high scorers did just the opposite -- replicates and extends earlier findings. Moreover, lower scorers spent more time considering answer alternatives and comparing answer alternatives to stem terms; they also tended to consider more of the alternatives. The general pattern of results is consistent with the view that high scorers use a "top-down", constructive strategy, while lower scorers use a more "bottom-up", eliminative approach. Additional analyses are currently in progress; however, at this point it can be clearly stated that high scorers are not simply faster or more efficient in processing than lower scorers. Rather, they appear to represent and solve problems in a **qualitatively** different way. Since these differences bear some resemblance to expert/novice differences in problem solving, implications for training will be discussed.

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